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Energy efficiency improvement of electric drive of cold pilgering mill

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Abstract. Different ways to improve the energy efficiency of electric drives of cold pilgering mill are considered. Mathematical modeling methods represent studies according to which it is possible to evaluate quantitatively the energy savings. For example, cold pilgering mill 450 shows the mean square of the armature current of the main drive motor related to critical frequency of the speed loop. The possibility of energy saving by previous field weakening of the motor before the operating cycle of rolling is considered. The optimal energy saving points of supply and termination of the pulse are determined by the field weakening. The correlation of the parameters of the dynamic units and the change of the electric drive work schedule provides the greatest loss reduction in the main drive of the cold pilgering mill stand based on the conditions. Activities aimed at improving energy efficiency of electric drives of mills of this group are reviewed, which reduces the electric energy consumption for the cycle rolling by 20-25 %.

1. Introduction

The main drive of a stand cold pilgering mills seamless pipe has an irregular periodic load curve of the operating device [1]. This fact leads to an overstatement of the installed capacity of power facilities. Electric drives of the mills of the reporting group realized on the basis of DC drives, in which a significant portion of the electrical losses is a part of the variable losses in the motor. The question of the modernization relevance, taking into account the significant productivity and capacity of power facilities, is dictated by the fact that most of the mills are working with old control schemes. Due to the updating of the electric drive elements, methods and control systems, it becomes possible to estimate the resources of energy saving in the electric drive for these types of mills [2].

2. Statement of energy saving problem

The mills of the considered groups of the main drives of the stands, implemented on the basis of the DC drives, are designed by the principle of minor regulation. Among related studies aimed at improving the efficiency of pilgering mills, it is possible to note the work, based on the decrease of the rate of the rectified EMF thyristor converter due to the automatic correction of the EMF of the motor when reducing the consumption of reactive power because of the main voltage deviation [3]. The object in this case was made by the broadband hot rolling mill.

Historically, that question of saving energy and reducing costs on power facilities was solved in the installed flywheel of open-loop electric drive systems. In [4], the methodology of the model calculations and the choice of a flywheel of the electric drives of the rolling mills of different types, having periodic load, are considred. There are, however, some enterprises manufacturing the electric drive of the cold pilgering mills of seamless pipes that do not have flywheels installed in the kinematic chain of the motor [5].

It is possible to bring an artificial softening of the mechanical characteristics in the electric drives of the powerful reversible hot rolling mill as another variant to solve this problem, where the system generator-motor was used, and the wound rotor induction motor (aggregates of Ilgner) was used to rotate the generator. This provides a reduction of the pulse load on the supply network in the moments when metal in the rolls [6].

Rolling on the cold pilgering mill is periodic; it provides irregular load torque for the electric drive during the cycle [7]. The process that requires the supply and rotates the workpiece means a lack of metal in the rolls, so the rolling tool is made so that the bite is formed between the rollers in the initial (I) and ending (II) positions during rolling [8].

From the point of view of energy saving, especially taking into account the achievements of power electronics [9], computer engineering, systems and ways of control, it becomes possible to estimate the resources of energy saving in the electric drive for these types of mills [10]. The energy efficiency of electric drives of mills for the cold pilgering mill are proposed to solve the reduced RMS current in the armature chain that is placed in the existing drive. Thus, it is possible to soften the mechanical characteristics of the closed loop system of the electric drive by preliminary field weakening of the motor because it increase the rated no-load speed before rolling [11].

3. Softening mechanical characteristics of the drive closed system

Mechanical characteristics of the drive closed system can be softened. The idea of the first method is to withdraw the part of the energy spent on the deformation of the metal from the rotating mass of the electric drive, thereby to increase the evenness of armature current during the rolling cycle and to reduce the magnitude of the losses [12].

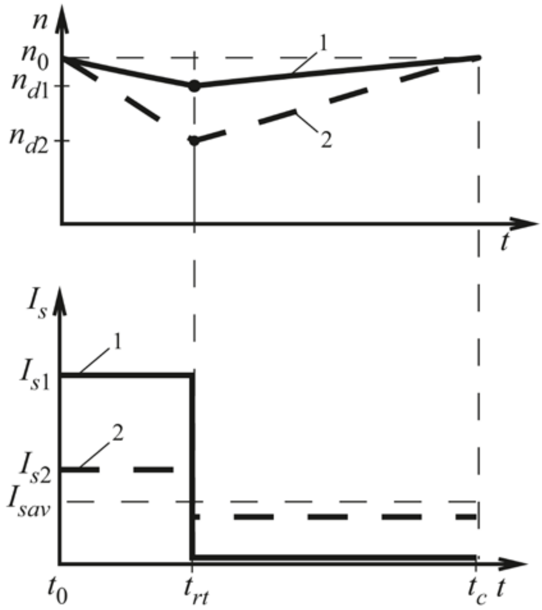

Figure 1. Simplified waveform of motor speed and armature current.

Figure 1 shows simplified waveforms of motor speed and armature current. The energy of the rotating mass of the electric drive can be defined as [13]:

$$W_{max} = J\cdot(n_o^2 - n_d^2)/2 \quad (1)$$

where W_{max} – rotating mass energy; n_o – the ideal no-load speed of the engine; n_d – value of dynamic decreased velocity; J – the moment of inertia of the electric drive. The energy savings will be more significant than most of the energy of W_{rol} required for rolling, which will be covered due to the energy of the rotating mass of the electric drive. Simplified waveforms (Figure 1, (1)) of current and velocity correspond to the original case mechanical characteristics of the closed system of the drive. Softening this feature allows reducing the RMS armature current to the average value (Figure 1 (2)), thereby reducing the amount of electric losses in the armature chain [14].

The estimation of reducing RMS current was carried out using the mathematical model of ‘electric drive – pilgering mill’ cold pilgering mill 450 of seamless tubes. This model included the main electric drive of the pilgering mill, which is the scheme of slave control [15]; the mechanical part, taking into account the mechanical transmission in the system; block cast torques rolling along with the motor shaft. References data of motor [16] are:

$$U_{ref} = 620\ V,\ I_{ref} = 2340\ A,\ M_{ref} = 310.2\ kN \cdot m \tag{2}$$

$$\omega_{ref} = 4.2\ rad/s,\ J = 19875\ kg \cdot m^2 \tag{3}$$

Softening mechanical characteristics is produced because of the decrease in the gain of proportional speed control K_{rs}. Figure 2 shows the ratio of RMS armature current to the speed control loop critical frequency. If we choose critical frequency of 10 rad/s, the RMS current value is reduced by 12 %. The real decrease in the RMS current (up to 50 %) is achieved only when [17].

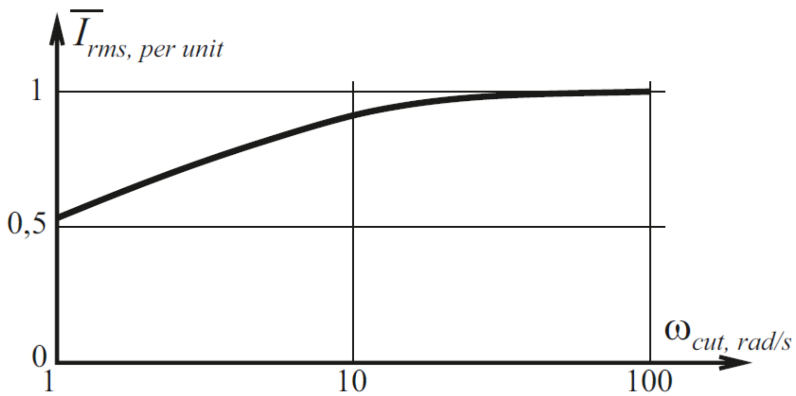

Figure 2. Dependence of RMS armature current of critical frequency speed control loop.

Low critical frequency and significant drawdown speed cannot be tolerated in real systems. As a result, the energy savings obtained per unit of output due to lower productivity of the mill are insignificant. This fact is connected with the cold pilgering mill 450 due to the fact that rolling time t_{rt} is relatively large, about 40 % of total cycle t_{tc}. The mass energy of the drive will be better if the rolling time is much less than the time of the entire cycle [18].

4. Preliminary field weakening before impulse stroke

The idea of the second method for energy saving is to use high-speed differential Δn_d at the stage of the imposition of load torque, to prevent a significant reduction in the average rolling speed. This is possible if at the stage of cycle, when the metal is not in the rolls, we increase the speed of the drive considerably above the ideal no-load speed of the drive at the rated voltage in the armature, i.e. at the cost of preliminary field weakening at the beginning of the impulse stroke [19].

Before each rolling cycle, the drive speed is artificially increased to n_{01} with weakening motor field, thereby achieving an increase of the RMS of speed per cycle. In the article, by the example of cold pilgering mill 450, we will consider the effect of the degree of flux attenuation of drive Φ (initial overspeed n_{01}) relatively the RMS current of the armature and the output of the mill [20]. At the same time, the speed limit should be set, based on the conditions of limitation impulse loads in the mechanical equipment for the metal pickup. Because the field weakening process occurs due to dynamic, it is also important to choose the time of pulsing and pulse stop during the field weakening (Figure 3). The problem unfolded in the function of the angle of rotation of the rolls, since all state variables are easier and clearer considered by this parameter. Figure 4 shows the relation of armature current RMS to the rotation angle of rolls α_{pre} corresponding to the start pulse to supply field weakening. The greatest effect for energy saving of cold pilgering mill 450 is obtained by the flow of drive F = 78 % of the nominal rate, α_{pre} = 0.75 *rad*, and was about 25 %.

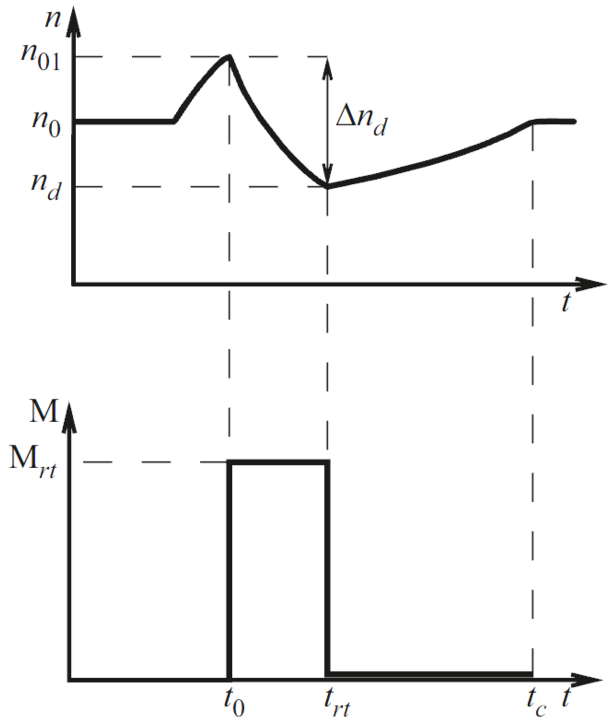

Figure 3. Preliminary field weakening.

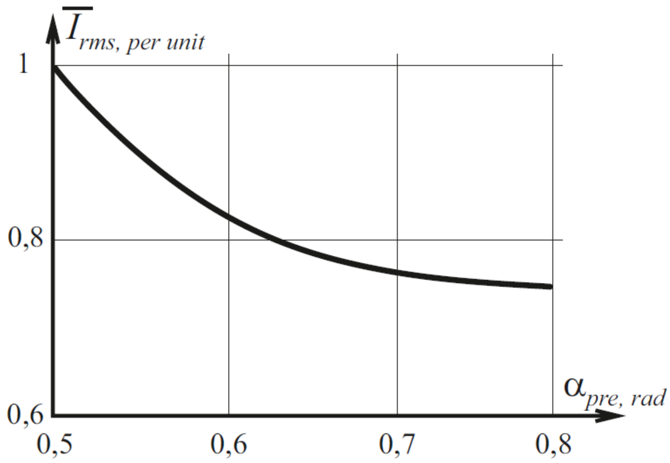

Figure 4. Dependence of RMS current of armature on angle of rotation of roll; pulse corresponds to the start of field weakening.

5. Conclusion

This article discusses the ways to improve the energy efficiency of the electric drive of cold pilgering mills. As a result of solving the problem, we have identified conditions that allow justifying the ratio of the dynamic chains and making changes in the work schedule of the drive, which provides the most effective reduction of losses in the drive of the stand roll cold pilgering mill.

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